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OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: 28 April 1972

Project Title: "Semiconductor Electron and X-Ray Detector System for Flourescence and Auger Investigations"

Project No: G-33-647

Principal Investigator Dr. R. W. Fink

Sponsor: National Science Foundation

Agreement Period: From May 1, 1972 Until October 31, 1974*

*24 month budget period plus 6 month's for fulfillment of any remaining grant obligations.

Type Agreement: Grant No. GP-33522

Amount: $25,000 NSF Funds (G-33-647)
3,509 Ga. Tech Contribution (G-33-337)
$28,509

Reports Required: Annual Report
Final Report

Sponsor Contact Person (s):

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Assigned to: School of Chemistry

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OFFICE OF CONTRACT ADMINISTRATION

RESEARCH PROJECT TERMINATION

Date: December 8, 1975

Project Title: Semiconductor Electron and X-Ray Detector System For Fluorescence and Auger Investigations

Project No: G-33-667

Principal Investigator: Dr. R. W. Fink

Sponsor: National Science Foundation

Effective Termination Date: 7/31/75 (Grant Expiration)

Clearance of Accounting Charges: by 7/31/75

Grant/Contract Closeout Actions Remaining: Final Fiscal Report.

Assigned to School of Chemistry

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G-33-647

PROGRESS REPORT
NSF Grant GP-33522

July 10, 1973

SEMICONDUCTOR ELECTRON AND X-RAY DETECTOR SYSTEM FOR INVESTIGATION OF HIGH-Z K-SHELL and L_1 SUBSHELL FLUORESCENCE YIELDS AND COSTER-KRONIG TRANSITION PROBABILITIES

Principal Investigator: Dr. Richard W. Fink
Professor of Chemistry
SS No. 382-22-2687

Georgia Institute of Technology
Atlanta, Georgia 30332

The electron detection system discussed in the original proposal for NSF grant GP-33522 has been designed to detect low-energy (10 - 100 keV) conversion and Auger electrons with good resolution and high efficiency. The system was delivered on June 5, 1973, but has been returned to the vendor for repair of a malfunction and is expected back soon. The system employs a liquid nitrogen cooled Si(Li) semiconductor detector, mounted with a source holder and vacuum interlock in an evacuated counting chamber. Our specifications further require that the system remain oil-free during long counting periods, and thus oil-free pumping is used, that interchange of radioactive sources be effected through an air-lock system, and that a low-energy (3 - 100keV) photon detector be easily placed in a location suitable for coincidence counting. The system is shown in the photographs of Figs. 1 and 2.

In Fig. 1 at the left is shown the dewar for cooling, the counting chamber, the air-lock gate-valve system, and the sample-changing rod, in order from bottom to top of photo. To the left of the counting chamber is the preamplifier, and on the right in Fig. 1 is a cryosorption pumping station with appropriate pressure gauging and valving.

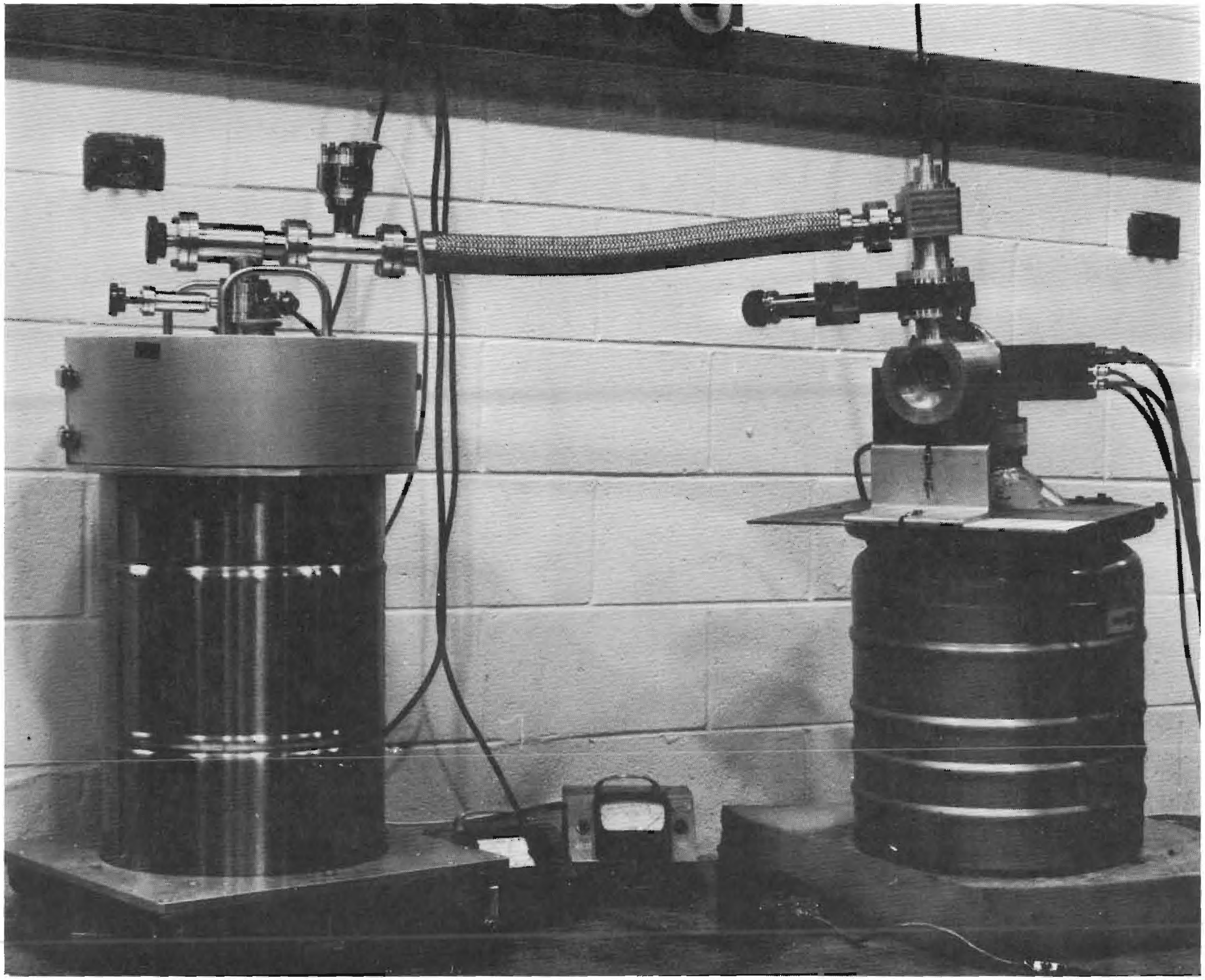

Figure 1. The Si(Li) Electron Detector System.

The pumping station is a California Physics Products Co. Model CSP-15 cryosorption pump. Its specifications include cryosprption on 15 lbs. of molecular sieve material at liquid N_2 temperature: under our operating conditions this provides a vacuum of $\leq 5 \times 10^{-3}$ Torr (theoretical minimum pressure is 4×10^{-6} Torr) in our system of ca. 20 liters evacuated volume and is reached from atmospheric pressure in ≤ 2 min. A 25 liter liquid N_2 charge of the cryopump lasts ≥ 3 days and is replenished at appropriate intervals. Saturation of the 15 lbs. of sieve material has not been reached in routine operation of up to two weeks duration. Pressure gauging is by a VEECO type DV-1M thermocouple gauge (not visible in Fig. 1) and by a VEECO type DG-2 discharge gauge (visible above the cryosorption pumping station). A 0.5 lb/in^2 spring-loaded outgassing valve and a 4 lb/in^2 rupture valve also are provided on the cryopump, together with a main valve. Connection to the counting chamber is by a flexible stainless steel hose. All plumbing to the joint mating the hose to the counting chamber is with copper gaskets.

The Si(Li) detector is a Simtec device and is designed to give high resolution low-energy conversion and Auger electron spectra and at the same time to be rugged and touch-proof: in the latter respect, to be able to withstand occasional exposure to atmospheric pressure while cooled to 77°K without damage to the detector. The active area of the detector is nominally 50 mm^2 with a 3 mm deep sensitive layer and the window is of diffused silicon with a deadlayer less than 0.2 microns. No gold plating is used as a contact layer on the detector face. The detector is mounted as a right circular cylinder with rear clamping, and no clamps or mounting rings are used at the front face, and no indium or materials of $Z > 14$ are used in or around the detector location (to avoid fluorescent x-rays). Only the active area is exposed to the radioactive source. An Al collimator of 1 mm thickness is used to eliminate the frontal deadedges. The distance from the front face with collimator to the Be window is less than 4 mm. The preamplifier is a Simtec Model P-11HR/CN and is integrally mounted with cooled components on the detector cryostat and is of the resistive feedback type.

The counting chamber shown in closeup in Fig. 2 was designed by us and constructed in the Georgia Tech shops. It was sent to the vendor for mounting of the detector and preamplifier. It is fitted with a Be window of 0.005-inch thickness for low-energy (3 - 100 keV) photon counting in coincidence with electrons. This window is visible at the center of the machined depression in the end of the chamber. A single gate valve isolates the cooled detector from atmosphere during sample changes: this is effected by push/pull of the rod (visible above the counting chamber in Fig. 1) and disconnection of the system at the O-ring flange immediately above the gate valve. Accurate reproducible counting geometry is ensured by fine tolerance machining of the source holder and the guide into the counting slot. The limiting vacuum seal in the system is at the push/pull rod.

Considerable delay has been experienced with this program owing to difficulties that the vendor has had in achieving our specifications for the Si(Li) detector. It has been very difficult for them to meet the requirement both for a ruggedized, touchproof window which is at the same time thin enough to transmit 3 keV photons or 10 keV electrons. We have specified a resolution equal to or better than 375 eV FWHM with 14.4 keV photons from a Co^{57} source, for the 50 mm^2 x 3 mm detector size, guaranteed for at least 1 year; the full-width at 1/10 maximum for photons shall not exceed twice the FWHM at any energy, and detection of 3 keV photons and 10 keV electrons is guaranteed, and will be tested with an open Co^{57} source of 7.3 & 13 keV electrons.

Personnel associated with this program are: Dr. Alexander Xenoulis (PhD, 1972, Nuclear Chemistry, Washington University, St. Louis,MO) who is supported half-time under this grant and half-time under the School of Chemistry NSF postdoctoral teaching fellowship program. Other participants (not supported by this grant) are: Dr. K. R. Baker and Dr. J. L. Wood, both postdoctoral investigators in nuclear chemistry in the School of Chemistry.

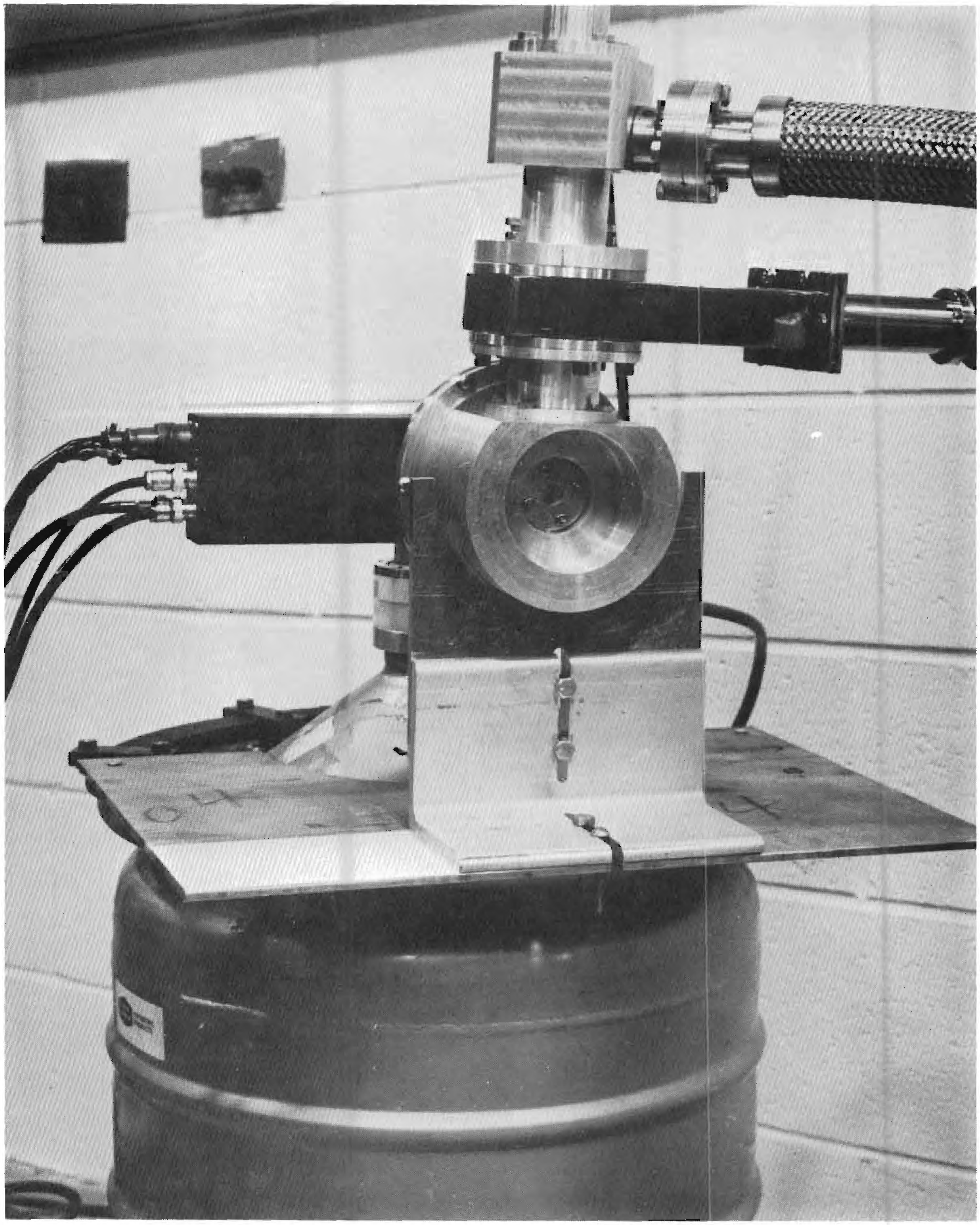

Figure 2. Closeup of Electron Detector Counting Chamber.

The first measurement with this system will be the three L-shell fluorescence and the three L-shell Coster-Kronig yields at $Z = 83$ from radioactive sources of Pb^{210}[RaD]. Other sources of interest, in addition to the list of experiments given in the original proposal, are 30 y Cs^{137} and 32.5 d Ce^{141}. Sources must be carrier-free and weightless, in order that very low energy electrons can be detected from them.

As a consequence of the delays we have experienced in getting delivery and in putting the system into operation, we need to request that NSF grant us an extension of the termination date of this grant (without new funds) by 6 to 9 months (ie, from April 30, 1974 to and end of 1974, Dec. 31).

ANNUAL PROGRESS REPORT
NSF Grant GP-33522

File: G-33-647

May 1, 1974

<u>Semiconductor Electron and X-ray Detector System for Investigation of High-Z K-Shell and L_1 Subshell Fluorescence Yields and Coster-Kronig Transition Probabilities</u>

Principal Investigator: Dr. Richard W. Fink
Professor of Chemistry

Co-investigators: Dr. John L. Wood and Dr. Kenneth R. Baker
Research Associates

School of Chemistry
Georgia Institute of Technology
Atlanta, Georgia 30332

The electron detector system discussed in the original proposal and in the previous progress report (July 10, 1973) is now operational. The system is designed to detect low-energy conversion and Auger electrons with good resolution and high efficiency. It employs a liquid nitrogen cooled Si(Li) semiconductor detector, mounted with a source holder and vacuum interlock in an evacuated counting chamber. The system is oil-free, due to the use of cryogenic pumping and metallic O-ring seals. The interchange of radioactive sources is effected through an air-lock system. A low-energy photon (3 to 100 keV) detector can be placed in a location suitable for performing electron-gated x-ray coincidence spectrometry. We were obliged to substitute a Kevex Si(Li) detector for the originally proposed Simtec one, owing to the failure of Simtec to meet our specifications, and, as discussed in the previous report, this cost a year's delay in this program. The Kevex detector meets all the previous specifications except the low-energy sensitivity for electrons. It apparently has a low-energy cutoff of about 25 keV at present.

We have met with two further difficulties in this program, one instrumental, and the other inherent to the measurements we are trying to make. The instrumental problem is the discovery that minute amounts of air leaking into the system (probably through the sample-chaning unit) produces a slow icing of the detector face. This does not seriously affect the detection of electrons at energies above 100 keV, but can cause serious loss of resolution at 50 keV and appears to prevent electrons of $\leq$ 30 keV from reaching the detector. This proves to be a serious limitation for detection of Auger electrons.

For the present, we are confining ourselves to the study of radioactive sources that emit conversion electrons with energies $\geq$ 100 keV. The second problem is contained in the nature of the measurement being made: to signal an L_1-subshell vacancy by detecting the L-conversion electrons of an M1 (or M4) transition and observing the coincident L x rays, in order to determine the Coster-Kronig transition probabilities f_{12} and f_{13} and the L_1-subshell fluorescence yield ω_1. Recent work in this laboratory has demonstrated that it is essential to have precise control over the width of the coincidence gate, in order to identify the effects of unwanted spectral components which occur in the gate. The problem has been solved by the use of digital gating. In the measurement discussed here, the following unwanted coincidences can arise:

(i) If the level deexcited by the M1 or M4 transition is fed by electron capture, the transition is in coincidence with vacancies resulting from the capture process, and thus, the use of radioactive sources which decay by electron capture are totally unsuitable;

(ii) If the level deexcited by the transition is fed by a transition which is measurably converted, the transition of interest is in coincidence with vacancies resulting from conversion processes in the feeding transition;

(iii) If the radioactive source decays by β^- emission, there is a β^- continuum which forms a background under the conversion electron lines. This background increases with decreasing energy, corresponding to the shape of the β^- spectrum. Such a background a low energy is in coincidence with all processes following the β^- decay step.

(iv) Although L shell conversion of M1 transitions is predominantly ($\geq$ 90%) in the L_1 subshell, the small ($\leq$ 10%) amount of conversion in the

L_2 and L_3 subshells must be taken into account, since vacancies so produced would otherwise appear to be the result of Coster-Kronig transitions. As a rule a 1% error in knowledge of the L-subshell conversion electron intensities translates into a 10% error in the Coster-Kronig yields; such an error is marginally acceptable. The L_1, L_2, and L_3 conversion lines can be separated only at high Z and then only partially.

We now have a solution to the above problems. We have recently acquired (as of April 15, 1974) a Nuclear Data ND-4420 dual-parameter computer-based analyzer system. This enables us to set large numbers of digital gates and so obtain precisely-gated coincidence spectra for large portions of the spectrum. In particular, it is now possible to determine accurately the effect of an underlying β^- continuum, of the tailing from a neighboring peak, or of the conversion of feeding transitions, on events in coincidence with a gate on the peak of interest.

In addition a careful consideration of suitable radioactive sources in the light of the above criteria (i - iv), suggests that the originally proposed ^{210}Pb, ^{137}Cs, and ^{141}Ce be replaced by ^{233}Pa. Although the ^{137}Cs β^- decay involves an M4 transition in ^{137}Ba, the critique outlined above for M1 transitions is applicable. The $^{233}Pa(\beta^-)^{233}U$ decay has a strong M1 transition at 312 keV. The source also is of great interest, since it provides a case for the study of the behavior of the Coster-Kronig L_2-L_3 transition probability f_{23} in the critical region Z = 92. We are proceeding with the acquisition of a ^{233}Pa source and are confident that we can now demonstrate the realization of the proposed L_1 subshell studies. We plan to reduce the detector icing by improvement of the system vacuum, so that the Auger electron studies can become feasible.

Personnel associated with this program are Dr. John L. Wood and Dr. K.R. Baker, both postdoctoral research associates in nuclear chemistry. Dr. A. C. Xenoulis was associated with this work prior to April 15, 1974.

G-33-647

Final Report
NSF Grant GP-33522
Expired July 31, 1975

SEMICONDUCTOR ELECTRON AND X-RAY DETECTOR SYSTEM FOR INVESTIGATION OF HIGH-Z K-SHELL AND L_1-SUBSHELL FLUORESCENCE YIELDS AND COSTER-KRONIG TRANSITION PROBABILITIES

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1.0 Measurement of L_1-Subshell Fluorescence Yields

Preliminary work on the measurement of the mean L_1-subshell fluorescence yield ν_1 of Gd (Z = 64) through the decay of 1.81 year ^{155}Eu has been attempted with the cooled Si(Li) electron detector-Si(li) x-ray detector coincidence system described in prior annual reports. This decay exhibits three γ-rays: 105 keV (E1 multipolarity), 86.5 keV (E1), and 60 keV (M1), which convert sufficiently in the L_1-subshell to allow detection of the L_1 conversion electrons for use as gates for the determination of ν_1. In this study, the thin ^{155}Eu source is placed inside the detector housing of the cooled Si(Li) electron detector through a vacuum interlock. This detector then is used to gate on L_1-subshell conversion electrons, and the L x-rays in coincidence are recorded by a second Si(Li) detector placed 180^o to the electron detector and outside the vacuum system of the latter. The principle of the measurement then is as follows:

The number of L x-rays in coincidence with the conversion electrons from one transition, $C_{L(Ce^-_L)}$ is given by

$$C_{L(ce^-_L)} = \frac{C_{L(p)} - 1/2[(x/y)C_{L(\beta)} + (x/z)C_{L(A)}]}{(1/2)C_p[x/y)C_\beta + (x/z)C_A]} \_\_ R \qquad (1)$$

where $C_{L(p)}$ is the number of L x-rays in coincidence with C_p gate events generated within an energy window of width $\underline{x}$ around the conversion peak of a given γ-ray transition. The quantity $C_{L(\beta)}$ is the number of L x-rays in coincidence with C_β gate events generated by a window of width $\underline{y}$ in a region of the electron spectrum just below the conversion electron peak, and $C_{L(A)}$, C_A, and $\underline{z}$ are the corresponding quantities associated with a window just above the conversion electron peak. The use of both windows corrects for the contribution of the β^- continum associated with the decay of ^{155}Eu. The quantity R is the ratio of the number of chance coincidence events per gate opening, experimentally determined by an independent measurement.

The term $C_{L(ce_L^-)}$ is given by

$$C_{L(ce_L^-)} = \bar{\omega}_L \bar{\epsilon}_L \tag{2}$$

where $\bar{\omega}_L$ is the mean L-shell x-ray fluorescence yield and $\bar{\epsilon}_L$ is the mean efficiency for detection of the L x-rays, and

$$\bar{\omega}_L = N_1\nu_1 + N_2\nu_2 + N_3\nu_3 \tag{3}$$

where $N_1 + N_2 + N_3 = 1$, representing the distribution of a single primary vacancy in the L shell among the three L-subshells. The quantities ν_1, ν_2, and ν_3 are the ratios of the total number of L x-rays arising from the filling of all three L subshells per initial vacancy in the L_1, L_2, or L_3 subshell, respectively.

If there were ideally conversion only in the L_1 subshell, then $N_1 = 1$, and $N_2=N_3=0$, giving

$$\nu_1\bar{\epsilon}_L = C_{L(ce_L^-)}$$

In practice it is possible to find cases where N_1 predominates, so that corrections for conversion in the L_2 and L_3 subshells can be made.

In the decay of ^{155}Eu, the conversion ratio $L_1/(L_2+L_3)$ for the 105 keV γ-ray is only about 2:1; however, the ratio for the 60 and the 86.5 keV γ-ray transitions are 9 and 8, respectively. The 60 keV transition gives conversion electrons just above 61 keV, just next to the 49.96 keV K_{β_2} x-ray, which thus interferes, and has the added disadvantage that the electron detector has poorer response to these lower energy electrons than it has for those from the 86.5 keV transition (E_{ce^-} = 78 keV).

Quantitative considerations in calculating the expected coincidence rates and values of ν_1 and ω_1 in the above equations involve the detectors coincidence geometry, resolution, and decay scheme characteristics of the radioactive source being studied. In the present equipment, the best relative efficiency ratio of the electron detector to the x-ray detector is only 625:1, due to geometry limitations of the vacuum housing of the windowless electron detector, and the electron energy resolution is relatively poor (7.8 keV FWHM at 113 keV), owing to ice formation on the detector. To obtain the L_1-subshell quantities ω_1, f_{12}, and f_{13}, the L x-ray detector must resolve the L_α, L_β x-rays and the L_1 and L_2 subshell components of the L_γ x-ray peak; however, the mean L_1-subshell fluorescence yield ν_1 can be obtained if only the L_α, L_β, and L_γ x-ray groups are resolved.

Those radioactive sources which have electron energies sufficiently high to be detected (> 50 keV) would fail to provide results in this experiment for either of the above reasons. For a nuclide undergoing β^- decay, the ce^- peak is riding on the β^- continuum, thus giving a true/chance coincidence ratio much less than unity; and in electron-capture decay cases, if the true to chance coincidence ratio is reasonable, the corrections for nuclear cascading are so large that the quantity being studied becomes only a small fraction of the observed coincidence events. These difficulties are illustrated in the examples given below.

The 50 keV L-conversion electrons from the 60 keV γ-ray transition in ^{155}Eu decay is unresolved from the 55 keV K-conversion electrons from the 105 keV transition, so that the 50 keV ce^- line is only 28% of the total peak counting rate. This gives a true/chance coincidence ratio of 1/3, which means that 25% of the true L x-ray coincidences observed arise from K-L vacancy transfers originating in K-shell conversion of the 105 keV transition. The 75 keV ce^- line from the 86.5 keV transition is 1.9% of the total counting rate in the electron detector, resulting in an expected L_α counting rate in the electron detector of 3.04×10^{-3}% of the total counts in the x-ray detector, and the true/chance ratio = 3/4.

The 290 keV L-conversion electrons in the decay of ^{233}Pa can not be resolved from the 300 keV K ce^- line from the 415 keV transition, so that 35% of the total L x-ray intensity due to L vacancies transferred from an initial K vacancy and the high background from the β^- continuum cause the true/chance coincidence ratio to be 7/8. Other cases are listed in Table 1, where

$$\frac{C_{L(ce^-)}}{I_{L_{x}(ce^-)}} = \frac{\text{Total } L_\alpha \text{ x-ray intensity in true coincidence}}{\text{Intensity of } L_\alpha \text{ x-rays from event of interest}}$$

In Table 1 are listed additional cases of the most favorable (at first glance) radioactive nuclides in the periodic table for L_1-subshell studies. They are selected on the basis of high conversion in the L_1 subshell, suitably long half-life, availability, and the fact that the transitions of interest are resolvable with present apparatus.

For the experiment to be successful, the following requirements must be met:

1) The correction for nuclear cascading should be small. This implies a ratio of $C_{L(ce^-)}/I_{L_x(ce^-)}$ (defined above) close to unity (column 5 in table 1). The only cases in Table 1 with small nuclear cascading are the 86 keV transition in the ^{175}Hf decay and the 482 keV transition in ^{181}Hf decay.

2) The true/chance coincidence ratio should be large (column 6). All the cases listed meet this requirement, except ^{159}Dy (58 keV) and ^{175}Hf (86 keV).

3) The counting rate per day of L_α x-rays in coincidence with L_1 conversion electrons (column 7), $I_{L_\alpha(ce^-)}$, should be sufficiently large. All the cases are feasible with a 10 day counting period, except ^{159}Dy (58 keV), ^{139}Ce (165 keV), ^{175}Hf (433 keV), ^{175}Hf (86 keV), ^{181}Hf (136 keV), and ^{181}Hf (482 keV).

Thus none of the cases selected as possibilities for this study is likely to give a successful experiment, because the present electron detector, due to icing and low coincidence geometry, is incapable of detecting electrons much below about 50 keV, or giving an adequate counting rate for electrons above 50 keV in the coincidence experiment. The cases where L_1-conversion electron lines having much less nuclear cascading exist, but where the electron energies lie in the inaccessible region below 50 keV for our detector are ^{201}Tl, ^{191}Os, and ^{195}Au. For this reason we proposed to carry out this measurement at the Lawrence Berkeley Laboratory, where suitable equipment exists. Moreover, some additional sources suitable for L_1-subshell studies can be produced at Berkeley and are not available at Georgia Tech (e.g., ^{243}Cm, ^{245}Cm, ^{247}Bk.

Thus, owing to the above limitations of the electron detector, due to poor coincidence geometry and poor resolution and inability to detect electrons below 50 keV, we proposed to utilize the excellent specialized facilities at the Lawrence Berkeley Laboratory.

(W. S. Lewis and M. S. Rapaport)

Table 1 - Possible Cases for L_1-Subshell Experiments[a)]

Decay Mode	Final Z	Nuclide $T_{1/2}$ E_α	L_1/L_{total}	Nuclear Cascading $\frac{C_{Lx(xe^-)}}{I_{Lx(ce^-)}}$	True/Chance	$I_{L\alpha(ce^-)}$ counts/day
EC	80	^{201}Tl 167	0.81	10	23	94.8
EC	80	^{201}Tl 135 73h	0.90	10^3	75	63.8
EC	78	^{195}Au 98.5 182.9d	0.89	910	100/1	487
EC	65	^{159}Dy 58 151d	0.75	10	2.7	35.8
EC	57	^{139}Ce 165 140d	0.92	$\sim 10^3$	10^3	13.5
β^-	77	^{191}Os 15d 129	0.64	10^3	47/<B>	89.3
EC	71	^{175}Hf 70d 433	0.97	6×10^4	0.55	1.4
EC	71	^{175}Hf 86	0.72	2.3	1/2	44.1
β^-	73	^{181}Hf 136	0.90	206	-	1.72
β^-	73	^{181}Hf 482 43d	0.68	1.05	866/<B>	35.3

a) Assuming 2×10^3 counts-s^{-1} (total) in e^- detector

Dr. Frank Asaro of the Chemistry Division, Lawrence Berkeley Laboratory, University of California, agreed to a collaboration between his research group and our group, and the measurements were to be done in Berkeley. The x-ray—electron coincidence system at Berkeley is suitable for electron energies well below the capabilities of the Georgia Tech system. The system at Berkeley has a vacuum chamber which initially is evacuated with a cryogenic pump, and then an 80 liter/sec ion pump is used to maintain a pressure of $\approx 10^{-8}$ Torr. The two high resolution Si(Li) detectors within the chamber are motor-driven from opposite sides, so that they can be brought to a distance of only 2 mm from the radioactive source. This system thus is the best available and would cost over $30,000 to reproduce at Georgia Tech. Moreover, all of the electronic modules needed for the coincidence measurements are in place at Berkeley.

Second, the radioactive sources to be studied (e.g., ^{201}Tl, ^{191}Os, ^{195}Au, ^{233}Pa, ^{243}Cm, ^{245}Cm, ^{247}Bk) are available at Berkeley, and a major requirement is that the sources be very thin. This requirement can be met by the use of the vacuum sublimation source preparation system that is part of Dr. Asaro's research facility, and such a system is not available at Georgia Tech.

Although the electron detector system at Georgia Tech is used for electron energies above 60 keV, there are some limitations that we have encountered with it (aside from the unavailable high-Z sources listed above and the vacuum sublimation equipment). The vacuum is maintained by cryogenic pumping to $\approx 10^{-5}$ - 10^{-6} Torr, so that a thin ice coating forms on the face of the electron detector. This seriously affects the resolution for electrons below about 50 keV. A further limitation is that the L x-ray detector which we place in coincidence with the electron detector is outside the vacuum chamber, and its distance is fixed (2.5 cm), which results in a very low coincidence detection efficiency for L x-ray—L_1 conversion electron coincidence measurements. For long runs, a special gain stabilizer is needed, which is available on the Berkeley system, but is not available on the Georgia Tech system.

For these reasons, we proposed supplemental funding from NSF, in order to use the superb system available at Berkeley, especially for low electron energies and high-Z sources. This supplemental grant for the investigation of high-Z L_1-subshell fluorescence yields, Coster-Kronig transition probabilities, and K-shell ionization during alpha decay was requested from NSF. Under this request the experimental study would have been conducted by Dr. M. S. Rapaport, research associate in the School of Chemistry at Georgia Institute of Technology, and was to have taken place at the Lawrence Berkeley Laboratory of the University of California, in collaboration with Dr. Frank Asaro. The request was for a stipend of $1000 per month for 6 to 9 months for Dr. Rapaport, while in Berkeley, California, plus $1000 for his travel and relocation expenses.

There having been no response to this request from the NSF, we were unable to carry out any measurements at Berkeley.

(Dr. M. S. Rapaport)

The proposed measurements of high-Z K-shell x-ray fluorescence yields ω_K according to the very accurate new method developed by us previously[1)] are not

[1] J. S. Hansen, J. C. McGeorge, R. W. Fink, R. E. Wood, P. V. Rao, and J. M. Palms, "Precision Determination of High-Z K-Shell Fluorescence Yields from ^{195}Au, ^{207}Bi, and ^{235}Np decays," Z. Physik 249, 373-385 (1972).

possible with the present windowless electron detector because of the necessity to measure K-Auger electron spectra in the region below 50 keV, where our detector is unreliable. These measurements could be performed with the system at Berkeley, as described above.

(R. W. Fink)

2.0 Measurement of L-shell Fluorescence Yields from Double Vacancy Atomic States in Indium

The electron capture (EC) decay of ^{113}Sn (115 days) is a very convenient source of double vacancy atomic states in indium (Z = 49). Vacancies in the K-shell are created both in K-capture decay (P_K = 0.75) to the 392 keV level in In as well as in the internal conversion of the 392 keV transition (α_K = 0.44). The decay of these K-shell vacancies through K-Auger electron emission leads to final atomic states in In characterized by double (LL)- and (LX)-vacancy states.

The principle is to measure L x-rays in coincidence with K-shell conversion electrons $C_{L(e_K^-)}$ and to compare them with L x-rays in coincidence with K_α x-rays $C_{L(K_\alpha)}$. The ratio of these two coincidence rates is related to the average L x-ray yields in the following way,

$$C_{L(e_K^-)} / C_{L(K_\alpha)} = (C_{e_K^-} / C_{K_\alpha})[n_{KL}(A)(\bar{\omega}_L(2) / \omega_{KL}) + n_{KL}(R)]$$

where $C_{e_K^-}$ is the number of K-shell conversion electron gate counts, C_{K_α} is the number of K_α x-ray gate counts, $n_{KL}(A)$ is the number of L-shell vacancies present in the double vacancy states per K-shell vacancy, $n_{KL}(R)$ is the number of L-shell vacancies present in single vacancy states (created by the emission of K_α x-ray) per K-shell vacancy decay, $\bar{\omega}_1(2)$ is the mean L x-ray fluorescence yield of the double-vacancy atomic states, and ω_{KL} is the mean L x-ray fluorescence yield following the K_α x-ray emission.

The values of $n_{KL}(A)$ and $n_{KL}(R)$ can be calculated from experimental data on Auger electrons and x-rays at Z = 49. If there is a substantial increase in the L-fluorescence yield of double vacancy atomic states as compared to that of single-vacancy atomic states, as has been expected from studies at lower Z in charged particle bombardment studies, this experiment can give results to an accuracy in the range 10 - 20 percent, the main limitation in accuracy arising in our knowledge of the quantity $n_{KL}(A)$ at Z = 49.

A microCurie drop-evaporated source of ^{113}Sn was prepared on a thin Mylar film. High resolution, cooled Si(Li) detectors are employed to detect indium L x-rays ($\approx$ 3.5 keV), K x-rays (24 - 28 keV), and 392 keV K-shell conversion electrons. A fast coincidence system in conjunction with a dual-parameter ND-4420 multichannel analyzer is employed to measure the coincidence rates. A special feature of the decay of ^{113}Sn is that the 392 keV level is between atomic states created in EC decay and those created by internal conversion (i.e., no nuclear cascades).

In addition to the experiment described above which is currently in progress, an attempt will be made to find answers for some of the remaining questions concerning the EC decay of ^{113}Sn. For example, a better experimental value for P_K, the total probability for K-capture, or the ratio P_L/P_K, the ratio of probabilities for L-shell and K-shell electron capture, can be obtained using the fluorescence yields measured in the present experiment, if one can obtain an accurate value for the ratio of the intensities of L and K x-rays, I_L/I_K, in the decay.

Plans are underway to modify the geometry of the Si(Li) windowless electron detector housing to improve the coincidence geometry, which is too poor to permit L_1-subshell experiments as described above. This modification will also permit it to be used as an x-ray detector.

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3.0 Personnel

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